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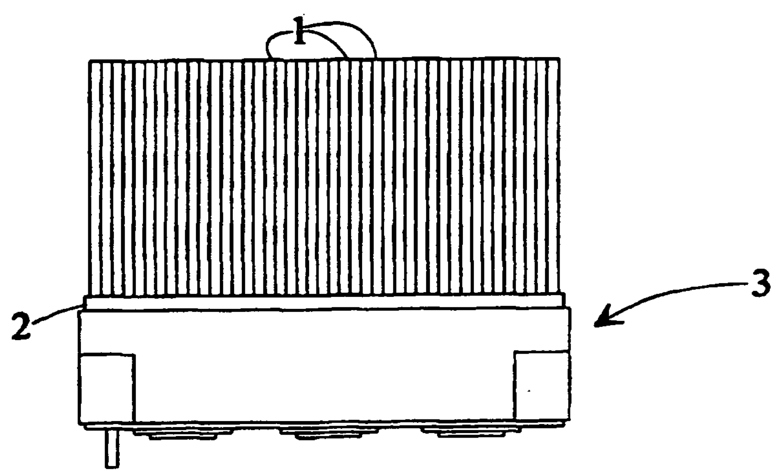
(54) Title: A METHOD OF BONDING HEAT SINK ELEMENTS TO A SOLID-STATE POWER COMPONENT AND A SOLID-STATE POWER COMPONENT EQUIPPED WITH AN INTEGRAL HEAT SINK

(57) Abstract

The invention relates to a method of bonding heat sink elements (1) directly to a solid-state power component (3) and a solid-state power switching component (3) equipped with an integral heat sink. According to the method, the solid-state power switching component (3) becomes equipped with an integral heat sink (1) of high heat transfer capacity to the ambient medium. According to the invention, the heat sink (1) is formed from a plurality of rod-like cooling fins (1) which are bonded by welding to the surface of the base plate (2) of the solid-state power switching component (3), essentially perpendicular to the surface of the base plate (2).



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A method of bonding heat sink elements to a solid-state power component and a solid-state power component equipped with an integral heat sink

The present invention relates to a method according to the preamble of claim 1 for bonding heat sink elements to a power solid-state component.

The invention also concerns a cooled solid-state power component equipped with an integral heat sink.

Conventionally, the heat sinks for electrical devices are made from a long bar of aluminium extrusion cut to suitable lengths. Extrusion is an easy method of producing a variety of extrusions of different sections, whereby the needs of different applications can be readily satisfied by designing a suitable section and thus producing a great number of different types of heat sinks. However, heat sinks with cooling fins made from an aluminium extrusion have several shortcomings particularly in applications related to the cooling of solid-state power switching components. This is because modern power switching components are capable of handling rather impressive electric power levels in equipment of a relatively compact size. When a high power is switched by a solid-state device, obviously a power loss is encountered resulting in internal heating of the device. This heat is generated within a small area and its dissipation most typically occurs by convection to ambient air. The thermal transfer capacity of a convection-cooled cooling element is chiefly proportional to the surface area of the heat sink cooling fins. As the element size is almost invariably limited by the design constraints of the power-handling equipment, the cooling performance of a cooling fin element with given size is determined by the packaging density of the cooling surface area in a given volume.

The cooling surface area of heat sinks made from a continuous section is limited by the minimum practicable thickness of the heat sink cooling fins. To make the manufacture of a continuous section of cooling fins possible, the fins protruding from the base part of the continuous section must have a sufficient thickness and a sufficient air gap must be provided between them to facilitate the extrusion of the continuous section as well as the making of the extrusion die. Using conventional extrusion techniques, it is not always possible to achieve a sufficient cooling surface area due to the above-mentioned constraints. Therefore, heat sinks fabricated from an extrusion are practical in sufficiently large series only, because an expensive die must be made separately for each extruded cross section. Products manufactured in small series only must resort to commercially available extruded heat sinks, whereby the product may possibly become bulkier and the latitude of design freedom curtailed. As a great number of electrical equipment today and in particular drive systems utilizing power electronics are designed and manufactured for a dedicate purpose, whereby the product design is specially optimized for the application, the production series will remain small. Here, the use of heat sinks made from an extruded section is not a viable alternative for a small batch production plan due to the long order times and large production series involved therein.

Attempts have been made to replace heat sinks made from an extruded section by different kinds of heat sink assemblies produced as combinations of discrete parts. The heat sink parts are generally bonded to each other by thermocompression bonding, but also a number of heat sink structures are being made using electron beam welding, laser welding, adhesive bonding, soldering and other conventional bonding methods. In thermocompression bonding the parts to be joined are generally machined so that one

of the parts has a recessed bonding area, while the other part has a compatible mating area, whereby either of the bonding areas is provided with wedge-shaped bumps. When the mating areas are pressed against each other, the bumps will be deformed and a solid metallurgical bond will be formed by cold pressure welding between the parts. While such a bonding method is functional in principle, its tight manufacturing tolerances make it prone to production errors and material defects. Such a manufacturing method presupposes long series, and as the parts to be joined must be fabricated using manufacturing methods capable of tight tolerances, the tooling costs will become excessive. Therefore, also this manufacturing method is not applicable to customer-oriented small batch production.

Heat sinks made from different extruded sections and bonded using various bonding methods are principally hampered by the same shortcomings as heat sinks made using compression welding, that is, the parts of the heat sink must be manufactured in large series from, e.g., an aluminium extrusion, whereby modifications of the heat sink become difficult and the heat sink assembly will often be clumsy due to the complicated shape of the parts. To be able to assemble heat sinks of different sizes, often a number of different kinds of parts are needed causing extra costs and inflexibility in storage and production.

Particularly solid-state power switching devices are conventionally mounted on their heat sinks using between the bottom of the power switching device, i.e., the surface to be cooled, and the heat sink, i.e., the cooling surface either purpose-formulated silicon-grease-based thermally conducting compound, or alternatively, an equivalent thermally conducting pad of a resilient material that may be, e.g., glass-fiber-reinforced silicon

polymer filled with particles of a material of high thermal conductivity such as aluminium oxide or boron nitride, for instance. The use of a thermally conducting compound or resilient pad in the gap between the device and the heat sink is necessary to fill the air pockets which otherwise might remain between the contact surfaces due to their imperfect mating. The thermal conductivity of air is known to be poor.

Also thermally conducting compounds have a number of shortcomings of which the most complicated are the need for flawless mounting of the solid-state device, the poor repeatability of such a mounting operation, and the tendency of the thermal compound to disintegrate with time, whereby the thermal conductivity over the device case-to-sink contact drops and the internal junction temperature of the device will be elevated. This will further lead into premature failure of the solid-state device. Moreover, as the thermal compounds contain silicon-based greases, they will soil the working environment during their application on the heat sinks, and furthermore, by evaporation release vapours that may deteriorate equipment reliability by forming harmful insulating films on, e.g., the electrical contact surfaces of connectors in signal processing electronics equipment.

Thermally conducting pads are free from the above-described disadvantages as they are made from a more solid material, which does not release vapours, for instance. Wider use of thermal pads is hampered by their high price when their thermal performance is elevated to the same level with the silicon-grease-based thermal compounds. Thus, the use of pads will be limited to small devices or special applications only in which electrical insulation capability may additionally be required.

However, thermal compounds and thermal pads alike are handicapped by their poor thermal conductivity in comparison with, e.g., that of those metals most conventionally used as the cooled surfaces of power switching devices and the base material of heat sinks. In practice this means that at typical heat flow rates through the base plate of power switching devices, the temperature difference across the interface between the cooled base plate surface and the heat sink will be approx. 10 - 15 K. This further means that the heat sink must be designed for a correspondingly higher cooling effect to keep the device junction temperature below maximum allowable value. Obviously, a heat sink dimensioned for a higher cooling effect invariably increases the production costs.

It is an object of the present invention to overcome or minimize the above-described disadvantages. While the invention can be applied to all types of solid-state power devices, it finds a particularly wide use in applications to, e.g., modular power electronics components having an insulated base plate. Power electronics devices of this group are, e.g., power diodes, thyristors, bipolar transistors, FETs, IGBTs, GTOs and the like.

The goal of the invention is achieved by virtue of bonding a plurality of rod-like cooling fins by welding essentially perpendicularly to the surface of the power device base plate so as to form a pattern with an optimized cooling effect.

More specifically, the method according to the invention is characterized by what is stated in the characterizing part of claim 1.

Furthermore, the power device equipped with an integral heat sink according to the invention is characterized by what is stated in the characterizing part of claim 4.

The invention offers significant benefits.

By virtue of achieving heat transfer directly from the power switching device to the cooling fins without using a thermal compound or pad as the transferring medium, the above-mentioned temperature difference over a conventional thermal contact is avoided. This means that the cooling fin array can be designed for a smaller thermal resistance to the ambient air, whereby either the production costs can be lowered, or alternatively, the junction of the solid-state device can be run at a lower temperature, whereby improved reliability is attained.

In the following the invention will be examined in greater detail with reference to exemplifying embodiments illustrated in the appended drawings, in which

Figure 1 is a side view of a solid-state power switching device equipped an integral heat sink according to the invention;

Figure 2 is a top view of the solid-state power switching device shown in Fig. 1 with the cooling fins;

Figure 3 is an end view of the solid-state power switching device shown in Fig. 1 with the cooling fins; and

Figure 4 is a ten times enlarged detail of the solid-state power switching device shown in Fig. 1 with the cooling fins;

Referring to Figs. 1 - 4, the base plates 2 of solid-state power switching devices 3 shown therein are conven-

tionally made from a 3 - 6 mm thick copper plate, while the rod-like cooling fins 1 are of aluminium or copper. The welding method used herein is capacitor discharge welding permitting extremely fast and reliable interbonding of different metals. In capacitor discharge welding, energy stored in a capacitor is discharged by means of, e.g., a thyristor switch through an intermetal contact to be welded, whereby the arc struck at the contact releases such a short-duration pulse of high energy density at the point of discharge that causes local melting of the contacting surfaces of the objects to be welded. As the objects are simultaneously pressed together, such a bond 4 as is shown in Fig. 4 will be formed at the cooling of the melted area. Typical burning time for the arc is about 100 μs. In detail, the manufacturing method is carried out as follows:

Solid-state power switching components 3 are dispensed from above onto the production line with their base plate 2 oriented upward and becoming attached in a jig of the welding station to a grounding electrode of the welding equipment typically from points 5, which are provided in the base plate 2 of the power component 3 for the standard fixing screws of the component. Above the base plate 2 of the power component 3 is located a purpose-designed manipulator carrying a plurality of clamping holders into which preformed rod-like cooling fins 1 are inserted at desired spacings forming a fin row equal to the width of the power component base plate 2. The holders are individually springed and provided with inertial masses compatible with set welding parameters. Each of the holders is connected to second electrode of the welding equipment. The type code of the power component 3 is given to the manipulator control logic either automatically by reading a bar code or manually. Such a bar code may additionally be used for automatic

setting of welding parameters and defining the placement pattern of the fins.

From another place the production line receives rod-like cooling fins 1, which are formed to their final shape by straightening and cutting metal wire paid off from a coil into fins of desired length. The ends are cut so that one end forming the tip of the fin in the heat sink is cut straight, while the other end still pointing toward the coil is shaped into a pointed end as typically required in capacitor discharge welding. The fin 1 cut free from the coil is guided with its pointed end entering the first vacant fin holder so deep that the pointed end remains resting on the surface of the power component base plate 2. These work steps are repeated until all holders are loaded with fins. The manipulator is programmed for each different type of power component 3 to leave those holders free of the cooling fins that coincide with the points 5 of the component fixing screws.

Next, the fin holders are individually tightened with the help of, e.g., pneumatic cylinders about the rod-like cooling fins 1 inserted therein, after which the manipulator starts to press the springed holders against the base plate 2 using a force preset in the welding parameters. In the manipulator each fin 1 is now connected to its dedicated capacitor welding equipment and the welding operation can be started. Welding occurs typically as a sequence of separate discharges proceeding over the base plate 2 fin by fin, whereby the contact of the grounding electrode to the base plate 2 will not be loaded by the entire sum of the discharge currents. Prior to starting the welding phase, the welding area may be wetted by atomized water which will vaporize during welding and thus remove the spatter which otherwise might remain on the welding area.

The above-described fin insertion and welding steps are repeated until the entire surface of the base plate 2 of the solid-state power component 3 is covered by the cooling fins 1 bonded to form a desired pattern.

The definition solid-state power component includes in this context especially semiconducting power components.

Claims:

1. A method of bonding heat sink elements (1) directly to a solid-state power component (3), in which method

- the solid-state power switching component (3) becomes equipped with an integral heat sink (1) of high heat transfer capacity to the ambient medium, and

- the heat sink (1) is formed from a plurality of rod-like cooling fins (1) oriented essentially perpendicular to the surface of the base plate (2) of the component,

c h a r a c t e r i z e d in that

- the cooling fins (1) are bonded by welding to the base plate (2) of the solid-state power switching component (3).

2. A method as defined in claim 1, c h a r a c t e r - i z e d in that the cooling fins (1) are bonded typically using capacitor discharge welding.

3. A method as defined in claim 1, c h a r a c t e r - i z e d in that the cooling fins (1) are bonded in a welding sequence carried out fin by fin.

4. A solid-state power switching component equipped with integrally bonded cooling fins, said component comprising a solid-state power device (3) and a plurality of rod-like cooling fins (1), which are bonded to and oriented essentially perpendicular to the surface of the base plate (2) of the solid-state power component (3) for the purpose of transferring dissipated heat away from said solid-state power switching component (3), c h a r a c -

t e r i z e d in that the cooling fins (1) are bonded by welding to the base plate (2).

5. An elongated, rod-like heat sink element (1) for a solid-state power switching component, c h a r a c - t e r i z e d in that the end of the heat sink fin element (1) which is to be bonded to the solid-state power switching device (3) is pointed in the fashion required in capacitor discharge welding.

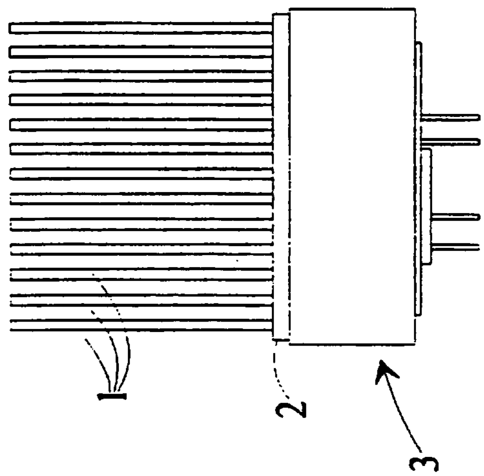

Fig. 3

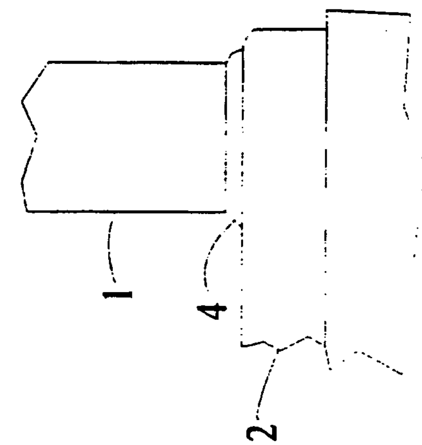

Fig. 4

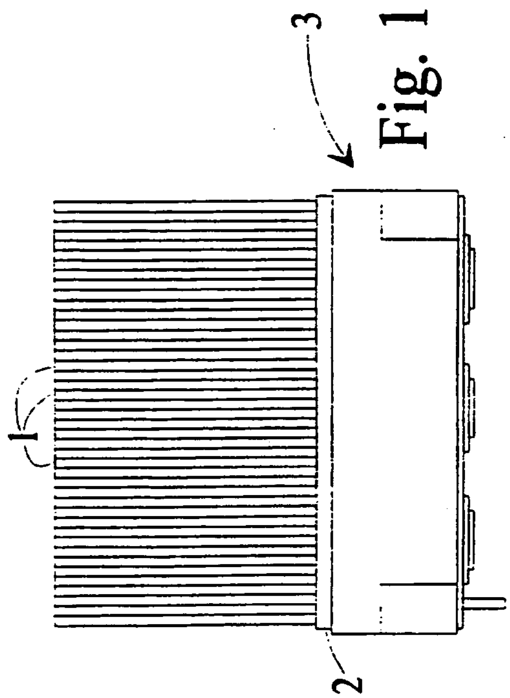

Fig. 1

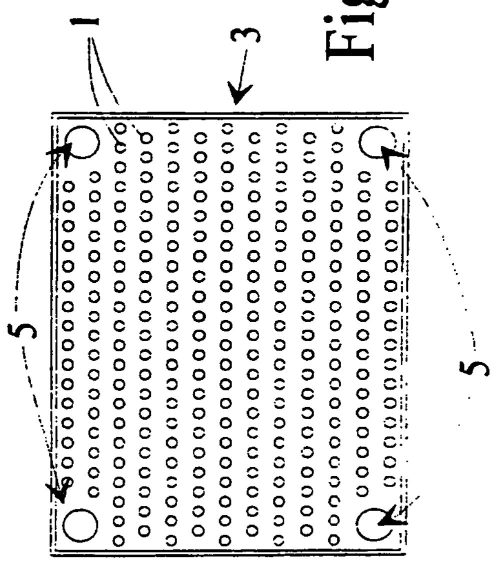

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 95/00702

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H01L 21/50, H01L 23/367

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

DIALOG; 2, 350, 351, 434

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 3602163 A1 (TELEFUNKEN ELECTRONIC GMBH), 30 July 1987 (30.07.87), column 3, line 10 - line 46, figures 1,2, claims 1,2, abstract --	1-5
Y	US 4541004 A (RICHARD M. MOORE), 10 Sept 1985 (10.09.85), column 3, line 8 - line 18, figures 1, 2, claims 1-5 --	1-5
A	US 4733453 A (JOHN H. JACOBY), 29 March 1988 (29.03.88) --	1-5

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
4 June 1996	07 -06- 1996
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INTERNATIONAL SEARCH REPORT

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4682269 A (MARTIN J. PITASI), 21 July 1987 (21.07.87) --	1-5
A	GB 2107516 A (UNITED KINGDOM ATOMIC ENERGY AUTHORITY), 27 April 1983 (27.04.83) -- --------	1-5

INTERNATIONAL SEARCH REPORT
Information on patent family members

01/04/96

International application No.
PCT/FI 95/00702

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DE-A1- 3602163	30/07/87	NONE	
US-A- 4541004	10/09/85	NONE	
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